BELLCOMM, INC.
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B70 07056

SUBJECT: A Philosophy for LRV Testing on the Moon - Case 320

DATE: July 17, 1970

FROM: P. Benjamin

ABSTRACT

Consistent with a program goal to maximize the scientific return of the missions, the primary purpose of the LRV is to enhance this return rather than to obtain data upon the characteristics of wheeled vehicles on the lunar surface. Proposed LRV tests which can legitimately be considered to contribute to an increase in scientific return must therefore be distinguished from those which may be of engineering interest but do not increase the scientific value of the mission.

The following are proposed as a possible set of criteria for judging proposed LRV tests:

1. Does the proposed test provide data which can be judged in advance to have a large potential for impact upon mission planning?

2. Does the test propose to examine characteristics or conditions which are typical of the types of missions which are planned?

3. Does the proposed test investigate systems which are critical to the mission?

4. Is the parameter to be investigated within bounds which are critical to the current or planned missions?

5. Can the information desired be obtained through analysis of data obtained from the traverse itself?

6. Can the information desired be obtained by appropriate earth based tests, including the use of simulation facilities?

7. Is the proposed test of general significance to lunar surface mobility beyond the current state of the art and independent of LRV systems?

These criteria are designed to establish the operational utility of the proposed test, and to attempt to determine whether the information resulting from the test will be useful in increasing significantly the efficiency and effectiveness of the current or future traverses.

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MEMORANDUM FOR FILE

The LRV has been developed to provide additional mobility to astronauts on the lunar surface and thus to obtain a wider and more significant sampling of lunar geology than would have been available without a mobility aid. The primary purpose of the LRV, then, is to enhance the scientific return of lunar missions, rather than to obtain data upon the characteristics of wheeled vehicles on the lunar surface. It must be recognized, however, that a certain amount of data on LRV performance will produce valuable information on LRV operational capability which can then be used to modify succeeding traverses in the current mission and aid in planning traverses for future missions, thereby increasing the scientific yield of the missions. A difficult decision is required, therefore, in distinguishing between those tests which can legitimately be considered to contribute to an increase in scientific return and those which may be of engineering interest but do not increase the scientific value of the mission. The three disparate viewpoints of LRV testing requirements - the scientific, the engineering, and the operational aspects - are presented and a set of criteria are developed which may help to determine how well proposed tests match overall program goals.

The Scientific Viewpoint

On one extreme it can be argued that any time not directly required for operations during an LRV traverse should be spent upon science. The rationale is that there are so few missions to the moon left in the current series of flights and so little opportunity to obtain scientific data that all available time should be spent upon scientific, rather than engineering, experiments. With the clues to the origin of the solar system possibly accessible on the moon, it is argued, it seems a poor allocation of resources to spend any time investigating the performance of a vehicle which will remain essentially the same for the remainder of the program. Minor changes to improve efficiency are not warranted by the time taken from science to investigate the engineering details. Engineering investigations to support some future, and as yet undefined, lunar program would seem highly suspect since by then technology will probably have changed sufficiently to make the present approaches to lunar mobility only interesting anachronisms.

The Engineering Viewpoint

A considerable amount of effort within the Apollo program has gone into the development of the LRV. After such an investment of time and energy, it is only natural for an engineer to want to determine how well his finished product has performed relative to his design. He wishes to test his assumptions and determine his success. Given only a small amount of experience with the LRV in the lunar environment many questions and unknowns which plagued the designers can be quickly settled. Large design margins to provide for these uncertainties can be modified to provide an optimum design. If appropriate design changes are made, this can help both science, in providing a better vehicle, and engineering, in learning more about lunar mobility aids. Besides, it can be argued, is it not as valid for an engineer to do research in lunar wheel/soil interaction as it is for a scientist to obtain a temperature profile of a tiny section of the lunar surface?

The Operational Viewpoint

It now appears as if it would have been well worth the science time lost if an engineering experiment on walking speeds and associated metabolic rates had been conducted earlier in the program. This would have supplied data of much value in planning future missions and could have eliminated margins which must now be kept at the expense of science time. Similarly, a few, simple tests on the LRV could supply much performance information which could prove most useful in mission planning. Time taken in determining more efficient ways to use the LRV could reduce overhead and increase scientific return of the missions. Thus, it is pointed out, a small initial investment of time in simple LRV tests can result in procedures changes which can modify succeeding traverses in the current mission and provide data to allow more effective planning of future missions, with consequent benefits to science.

Discussion

As with most such difficult questions, the determination of how much and what testing to perform on the LRV when it is on the lunar surface has many valid points on all sides of the argument. The tradeoffs between scientific investigation and engineering and operational tests are murky, and it does not appear that there is a clear-cut line between useful LRV tests and those which only degrade science return. Accordingly it is with some trepidation that the following are proposed as a possible set of criteria for judging proposed LRV tests:

1. Mission planning impact - Does the proposed test provide data which can be judged in advance to have a large potential for impact upon mission planning? Clearly there is an almost unlimited number of tests which could provide data with some impact upon mission planning, and, after some experience on the lunar surface, it may even turn out that a few of these are critical. The proliferation of such tests could result in a serious decrease in scientific return, so the establishment in advance that their potential impact as significant, regardless of the results of the test, is one means to maintain a reasonable bound on the number of tests. Other, less critical tests could be held in reserve and introduced in real time if initial LRV experience indicated that they may be of critical importance.

2. Typical of missions - Does the test propose to examine characteristics or conditions which are typical of the types of missions which are planned? Extensive testing of LRV performance and wheel/soil interaction in the mare adjacent to the LM may be of little value if most of the traverses are planned for hummocky uplands with different slope distributions, soil types, rock sizes, and crater diameters. The primary desire is not for LRV performance data per se, but for data which corresponds to expected mission characteristics.

3. Mission critical - Does the proposed test investigate systems which are critical to the mission? A detailed examination of the accuracy of the navigation system may be of great interest to its designers but is of little value to the mission as long as the system is generally accurate enough to return the crew to the vicinity of the LM. An extensive determination of drive motor torque is probably not valid as long as the motors have the capability to perform the functions required in the mission.

4. Parameter within bounds - Is the parameter to be investigated within bounds which are critical to the current or planned missions? This criterion is related to the last one, and may help to define when a system might be critical to the mission. If all planned missions involve total traverse distances less than 50 km, it would not appear particularly worthwhile to determine whether the battery will support an 88 or a 92 km mission. Thus if the magnitude of the parameter to be tested is known in advance to be well beyond the value required by the missions, any time spent in testing exactly what that value is could proabably be better spent in scientific investigation.

5. Inherent in traverse - Can the information desired be obtained through analysis of data obtained from the traverse itself? It would appear that a large amount of LRV performance information could be extrapolated, with perhaps a minor amount

of degradation, from the data which is obtained in the course of the traverse. If a relatively accurate record of the exact route traversed is obtained, information such as battery thermal profiles as a function of speed and terrain can be roughly deduced from this and occasional status reports on battery temperature. Such data could be computed in real time for application to the current or succeeding traverses on the present mission, or post flight, for application to mission planning. Since all planned traverses will provide the crew with the capability to walk back to the LM from a disabled LRV, it is not necessary to validate the performance of any LRV system prior to the traverse in order to insure crew safety throughout the traverse.

6. Earth based tests - Can the information desired be obtained by appropriate earth based tests, including the use of simulation facilities? The thermal and vacuum effects of the lunar environment can be simulated adequately on earth so that tests relating to these effects generally can be performed on earth. Tests in areas such as thermal degradation of radiating surfaces due to dust accumulation might be performed on earth with analogs of lunar dust and, perhaps the application of some correction factor. Often a complex experiment on the moon can be reduced by obtaining one or two data points and then creating a model or earth based simulation to match these values. The ingenious development of appropriate models, correction factors, and simulations based upon small amount of actual lunar based data can often contribute greatly to the reduction of requirements for experiments on the moon.

7. General significance - Is the proposed test of general significance to lunar surface mobility beyond the current state of the art and independent of LRV systems? Exceptions to the above criteria would exist for tests of general engineering value independent of the LRV configuration. Generalized engineering tests of mobility systems parameters in the lunar environment would have to recognize that technology will probably change considerably between the current series of flights and man's next visit to the moon. Thus soil mechanics investigations might be justified but wheel/soil interaction tests depending upon the LRV wheel characteristics would be suspect.

Summary

The first 4 criteria are designed to establish the operational utility of the proposed test. They attempt to determine whether the information resulting from the test will be useful in increasing significantly the efficiency and effectiveness of the current or future traverses. Providing the value of the experiments is established by these criteria, the next 2 criteria ask whether there is any alternate way to obtain the information other than a formal experiment on the moon. The

final criterion is an engineering "escape clause" which should be used very sparingly and only with very careful evaluation. If there is an experiment of sufficient value and generality such that it is effectively investigating characteristics of the lunar environs, rather than the LRV, then it may be accepted under this criterion even while rejected by other criteria. Such an investigation, however, is really an experiment, rather than a test, and should probably be formally accpeted as a program experiment, recognized for its own merits, rather than being hidden as an LRV test.

The philosophy which underlies these criteria is that LRV tests must be consistent with a program goal to maximize the scientific return of the missions. Thus LRV tests should not be oriented toward verification of engineering design and validation of postulated performance characteristics. Nor is there any implicit value to the program in determining whether any specific assumptions made in LRV design were correct. The LRV tests which most contribute to the success of the missions are those which have a direct and significant impact upon traverse planning.

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